

[Note]

New record of *Sargassum filicinum* Harvey (Fucales, Phaeophyceae) in the Pacific Coast of Mexico

Luis E. Aguilar-Rosas^{1*}, Raúl Aguilar-Rosas², Hiroshi Kawai³,
Shinya Uwai³ and Enrique Valenzuela-Espinoza¹

¹Instituto de Investigaciones Oceanológicas, Universidad Autónoma de Baja California,
Apartado Postal 453, 22830, Ensenada, Baja California, México

²Facultad de Ciencias Marinas, Universidad Autónoma de Baja California,
Apartado Postal 453, 22830, Ensenada, Baja California, México

³Research Center for Inland Seas, Kobe University, Rokkodai, Kobe 657-8501, Japan

Sargassum filicinum Harvey, a brown alga (Phaeophyceae) native to Northeastern Asia, has been recently reported from the coast of Southern California (USA). Here we report the occurrence and range extension of this introduced species, as we found the alga at La Jolla and Rancho Packard in Todos Santos Bay, Baja California, Mexico. The first collections of *S. filicinum* correspond to several immature plants, found on September 8, 2005, drifting in the intertidal zone at La Jolla. Later on November 9, 2006, we found a well-established population in Rancho Packard in the middle intertidal zone to 2 m depth. Since *S. filicinum* is an annual monoecious species with air bladders, the risk there is a high risk of spreading rapidly along the Pacific, as in the case for *S. muticum*. The population in Rancho Packard extends 500 m along the coast, consisting mainly of young plants with an average length of 30 cm and a density of 5 thallus/m². This is the first record of this invasive species for the Mexican Pacific coast, and it represents the southern limit along the Pacific coast of North America. This finding suggests that this invasive species has successfully colonized the Pacific coast of North America and its distributional range is still expanding.

Key Words: introduced species, invasive species, molecular identification, Pacific Mexico, *Sargassum filicinum*

INTRODUCTION

Our continuous monitoring program of benthic macroalgae along the Mexican Pacific coast has allowed us to record new distributional records for several species (Aguilar-Rosas and Aguilar-Rosas 1985; Aguilar-Rosas 1994; Broom *et al.* 2002 ; Aguilar-Rosas *et al.* 2004). On September 8, 2005, at La Jolla in Todos Santos Bay, Baja California, Mexico, we found a non-indigenous brown alga, identified as *Sargassum filicinum* Harvey. This species is native to the temperate coasts of Japan (Yoshida 1983) and Korea (Lee and Yoo 1992), was recorded recently for the first time along the Pacific coast of North America, with localized populations at Long Beach Harbor and Santa Catalina Island, near Los Angeles in Southern California, USA (Miller *et al.* 2006).

Sargassum filicinum is a species with a relatively restricted distribution in Northeastern Asian waters.

However, certain morphological characteristics, such as the presence of bearing air bladders and monoecism, may allow it to spread to other areas and it is therefore considered to be an invasive species (Okuda 1977; Yoshida *et al.* 1999; Miller *et al.* 2006). Many of these characteristics are shared with other invasive species, such as *Sargassum muticum*, which was unintentionally introduced to the Pacific coast of North America associated with young oysters and spread rapidly south along the coast (Aguilar-Rosas *et al.* 1993).

We recently found a well-established population of *Sargassum filicinum* growing in the intertidal and subtidal zone in locations where it had not been previously recorded. In this paper, we report the spread of *S. filicinum* into Todos Santos Bay near Ensenada in Baja California on the Pacific coast of Mexico. We provide a detailed description of its morphological and reproductive characteristics, as well as its habitat and geographic distribution in the study area.

*Corresponding author (laguilar@uabc.mx)

MATERIALS AND METHODS

The first specimens of *Sargassum filicinum* were observed and collected on September 8, 2005, and collected drifting in the intertidal zone at La Jolla in Todos Santos Bay, Baja California, Mexico ($31^{\circ} 43' 17''$ N and $116^{\circ} 40' 17''$ W) (Fig. 1). We conducted several subsequent samplings trips along the Pacific Coast of Baja California including Todos Santos Bay, and discovered a well established population of *S. filicinum* in Rancho Packard in Todos Santos Bay, Baja California, Mexico on October 8, 2006 ($31^{\circ} 46' 09''$ N and $116^{\circ} 41' 54''$ W). Plants were collected from the rocky intertidal and subtidal zone. Collections were placed in plastic bags and transported to the laboratory for immediate analysis. They were then fixed with 4% formalin seawater solution and mounted on herbarium sheets. A collection of specimens are deposited in the herbarium CMMEX of the Facultad de Ciencias Marinas from the Universidad Autónoma de Baja California (UABC) (CMMEX 4439, 4440, 4441, 4442, 4443, 4444) (Holmgren *et al.* 1985) and in the herbarium the University of California, Berkeley, California, USA (UC 1862395, 1862396, 1862397).

Observations were conducted using Zeiss Axioscope 40 microscope (Göttingen, Germany). Photographs of sections were taken on a with a Sony DSC-S85 digital camera (Tokyo, Japan). For species identifications, we compared our specimens with descriptions and illustrations of *Sargassum filicinum* in Chihara (1975), Miller *et al.* (2006) and with Japanese and California specimens. To confirm our morphological identification, the mitochondria cytochrome oxidase subunit III gene (*cox3*) was sequenced and compared with the reported sequence of the species from Japan and California (Miller *et al.* 2006).

RESULTS AND DISCUSSION

Distribution

The first collections of *Sargassum filicinum* along the coast of the Mexican Pacific were several immature plants, found on September 8, 2005, drifting in the intertidal zone at La Jolla. Later, on November 9, 2006 we found another population well established in Rancho Packard in the middle intertidal zone to 2 m depth in Todos Santos Bay, Baja California, Mexico.

Since the first specimens of *S. filicinum* along the Pacific coast of North America were found at Santa Catalina Island in Southern California (USA) in October

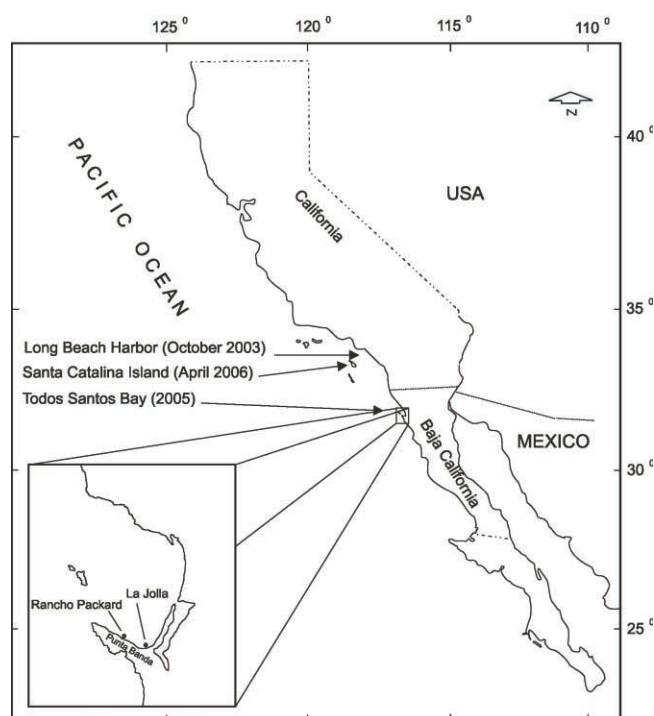


Fig. 1. Map showing the study site and collections sites.

2003 (northern limit) (Miller *et al.* 2006), our collections represent the first record of this invasive species in the Mexican Pacific. In addition, these findings extend the southern limit of *S. filicinum* in North America by about 300 Km, from Santa Catalina Island to La Jolla and Rancho Packard in Todos Santos Bay, Mexico (Fig. 1).

These findings suggest that the range of *S. filicinum* is still expanding along the Pacific coast of North America (including into Mexico). We suggest that dispersal will continue and that this species will colonize new localities, because habitats and environmental conditions in North America are similar to those in its native range. A similar pattern occurred when *S. muticum* when this Japanese species was introduced to the Pacific coast of North America in the 1940's (Scagel 1956; Nicholson 1979), and it is now recorded as far south as Guadalupe, Baja California Sur, Mexico (Aguilar-Rosas and Aguilar-Rosas 1993).

Habitat

Sargassum filicinum is found growing on rocks from the intertidal into the shallow subtidal to a depth of 6 m. In the intertidal zone it is found associated with *Lithothrix aspergillum*, *Corallina vancouveriensis*, *Sargassum muticum*, *S. agardhianum*, *S. palmeri*, *Dictyopteris undulata* and *Dictyota flabellata*. The studied population is found along 500 m in the protected coast of Rancho Packard in Todos

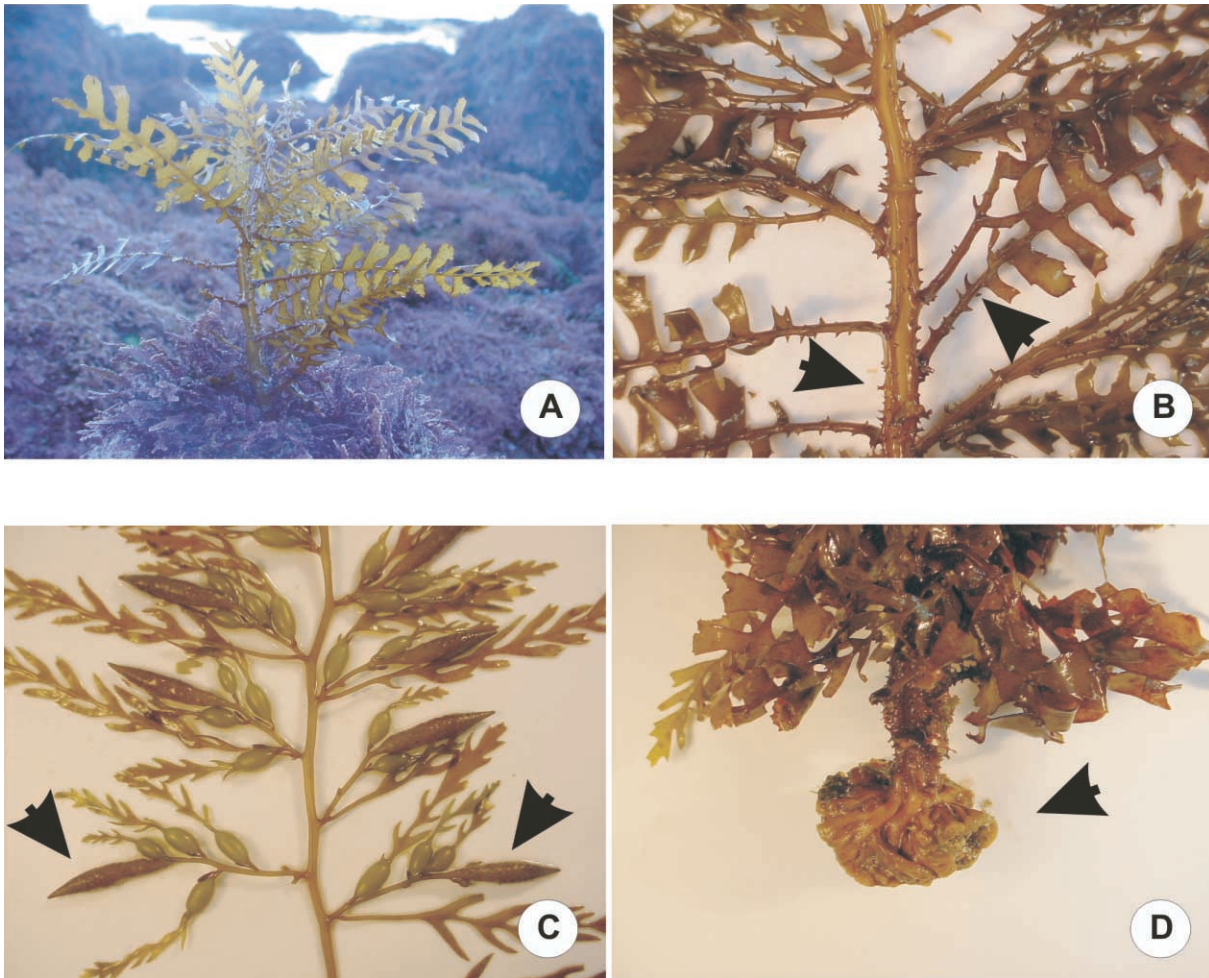


Fig. 2. *Sargassum filicinum* Harvey. a. Specimen collected on November 9, 2006 in Rancho Packard at Todos Santos Bay, Baja California, Mexico. Scale = 5 cm. b. Spiny terete stipe, bearing alternate spiny branches with notched vegetative leaves. Scale = 1 cm. c. Detail of the spherical/elliptical air bladders. Scale = 1 cm. d. Discoid holdfast having the very spiny stipe. Scale = 1 cm.

Santos Bay, at a density approximately 5 thallus/m².

Morphology, molecular identification and reproduction

The population of *S. filicinum* in the study area is mainly composed of young plants with an average height of 30 cm, but some fertile adult individuals with an average height of 80 cm are present. The erect thallus is medium brown to brown arising from a solid and rugose discoid holdfast having a spiny terete stipe bearing alternate spiny branches with deeply incised, often notched vegetative leaves (Fig. 2). The principal characteristic for identifying this species is by the form of the air bladders (pneumatocysts) which are spherical to elliptical (Fig. 2), while those of other species present in this area are spherical like *S. muticum*, *S. palmeri* and *S. agardhianum* (Abbott and Hollenberg, 1976). Miller *et al.* (2006) compared *S. filicinum* with a related Japanese

species *S. horneri* that has a considerably similar morphology, but *S. horneri* bears cylindrical air bladders. When the plant is mature, it forms receptacles 4 cm long, which appear as cigar-shape.

We utilized a 469 bp sequence of the mitochondrial *cox3* gene in the Baja California specimen and compared it to specimens collected in the Seto inland Sea, Japan and St. Catalina Island, CA. All of *S. filicinum* specimens examined had the same mitochondrial *cox3* sequence (accession number AB264797). A faster evolving gene is needed to determine the source of the introductions and examine the relationship between populations.

Introduction vector

The introduction of *S. filicinum* into the coast of Baja California may be correlated with the traffic of commercial vessels (including large Asiatic cargo ships) and tourist cruise ships visiting Ensenada harbor from

Southern California (Casarrubias-Garcia 2001). Todos Santos Bay is also a destination for recreational boats (sailing yachts, etc.) coming from Southern California and are considered to be potential vector for the introduction of marine species (Ribera and Boudouresque, 1995).

The introduction of *S. filicinum* in Todos Santos Bay may resulted from plants attached to ship' hulls, and/or from spores or embryos carried in ships' ballast water (Critchley *et al.* 1990; Piriz and Casas 1994; Forrest *et al.* 2000). It is also possible that since *S. filicinum* has pneumatocysts, it drifted south from Southern California on the California current (Fig. 1). Regardless of the mode of introduction, we are confident that *S. filicinum* is a recent introduction; two years ago we conducted surveys and made collections in the area around Rancho Packard and *S. filicinum* was not present.

The first specimens of *S. filicinum* along the Pacific coast of North America were found at Santa Catalina Island in Southern California (USA) on October 2003 (northern limit) (Miller *et al.* 2006); it is considered a highly invasive species, like *S. muticum* (Norton 1981) and *Undaria pinnatifida* (Forrest *et al.* 2000; Silva *et al.* 2002). It is well adapted for widespread dispersal and rapid colonization (Nyberg and Walentinus 2005), with morphological and reproductive characteristics, such as buoyancy and high reproductive output, which allow it to invade and establish successfully in new areas (Miller *et al.* 2006). Silva *et al.* (2002) suggest that eradication efforts of introduced species of macroalgae can be successful when the introduction is detected at an early stage (before spore release) and confined to a small area. As an example, *Caulerpa taxifolia* was introduced in 2000 and declared eradicated in 2005 (Merkel and Associates, 2005).

The discovery of these introduced macroalgal species in the Mexican Pacific coast is part of a continuous monitoring program at our University, and *S. filicinum* is now added to the list of introduced macroalgae in this region. Other well-documented introductions are *S. muticum* (Aguilar-Rosas and Aguilar-Rosas 1985; 1993), *Lomentaria hakodatensis* (Dawson 1944), *Cutleria cylindrica* (Aguilar-Rosas 1994), *Porphyra suborbiculata* (Broom *et al.* 2002; Aguilar-Rosas and Aguilar-Rosas 2003), *Undaria pinnatifida* (Aguilar-Rosas *et al.* 2004).

Ecological impact

It important to document these new findings, as well as the spread of the additional introduced species. The

recent introduction and establishment of *Sargassum filicinum* in Mexico will require attention, since there may be some negative ecological effects of this species. More ecological studies of *S. filicinum* and detailed surveys of their habitat requirements are needed to better determine the possible ecological impact of this invader on coastal communities.

ACKNOWLEDGMENTS

This work was supported by Institute of Oceanographic Research and Faculty of Marine Science of the Universidad Autonoma de Baja California, under the Program No 571 (10^a UABC Research program PIAC-CEC) and the monitoring program of Herbarium CMMEX. We thank Filiberto Núñez-Cebrero for assistance in the field and laboratory. Special thanks to Benjamin Ruttenberg for the English translation.

REFERENCES

- Abbott, I.A. and Hollenberg, G.J. 1976. *Marine Algae of California*. Stanford University Press, Stanford California.
- Aguilar-Rosas R. 1994. Notas ficológicas. I. Primer registro de *Cutleria cylindrica* Okamura (Cutleriaceae, Phaeophyta) para las costas del Pacífico mexicano. *Acta Botánica Mexicana* **29**: 55-60.
- Aguilar-Rosas R. and Aguilar-Rosas L.E. 1985. *Sargassum muticum* (Yendo) Fensholt (Fucales, Phaeophyta) en las costas de Baja California, México. *Ciencias Marinas* **11**: 127-129.
- Aguilar-Rosas R. and Aguilar-Rosas L.E. 1993. Cronología de la colonización de *Sargassum muticum* (Phaeophyta) en las costas de la península de Baja California, México (1971-1990). *Revista de Investigación Científica* **4**: 41-51.
- Aguilar-Rosas R., Aguilar-Rosas L.E., Ávila-Serrano G. and Marcos-Ramírez R. 2004. First record of *Undaria pinnatifida* (Harvey) Suringar (Lamariales, Phaeophyta) on the Pacific coast of Mexico. *Bot. Mar.* **47**: 255-258.
- Aguilar-Rosas R. and Aguilar-Rosas L.E. 2003. El género *Porphyra* (Bangiaceae, Rhodophyta) en la costa Pacífico de México. I. *Porphyra suborbiculata* Kjellman. *Hidrobiológica* **13**: 51-56.
- Broom, J.E., Nelson W.A., Yarish C., Jones W.A., Aguilar-Rosas R. and Aguilar-Rosas L.E. 2002. A reassessment of the taxonomic status of *Porphyra suborbiculata*, *Porphyra carolinensis* and *Porphyra liliputiana* (Bangiales, Rhodophyta) based on molecular and morphological data. *Eur. J. Phycol.* **37**: 227-23.
- Casarrubias-García A. 2001. Puertos, potencialidades y auge de los cruceros. *Mexicoa* **3**: 102-111.
- Chihara M. 1975. *Picture Book of Seaweeds*. Gakken Co. Ltd., Tokyo.

- Critchley A.T., Farnham W.F., Yoshida T. and Norton T.A. 1990. A biogeography of the invasive alga *Sargassum muticum* (Yendo) Fensholt (Fucales, Sargassaceae). *Bot. Mar.* **33**: 551-562.
- Dawson E.Y. 1944. The marine algae of the Gulf of California. *Allan Hancock Pacific Expedition* **3**: 189-454.
- Espinoza J. 1990. The southern limit of *Sargassum muticum* (Yendo) Fensholt (Phaeophyta, Fucales) in the Mexican Pacific. *Bot. Mar.* **33**: 193-196.
- Forrest B.M., Brown S.N., Taylor M.D., Hurd C.L. and Hay C.H. 2000. The role of natural dispersal mechanisms in the spread of *Undaria pinnatifida* (Laminariales, Phaeophyceae). *Phycologia* **39**: 547-553.
- Holmgren P.K. 1985. Additions to Index Herbariorum, Part I. The Herbaria of the World, Edition 7 (III). *Taxon* **34**: 735-738.
- Lee I.K. and Yoo S.-A. 1992. Korean species of *Sargassum* subgenus *Bactrophyucus* J. Agardh (Sargassaceae, Fucales). In: Abbott I.A. (ed.), *Taxonomy of Economic Seaweeds*. Vol 3. California Sea Grant Collage, La Jolla, California, pp. 134-147.
- Merkel and Associates 2005. Eradication and surveillance of *Caulerpa taxifolia* within Agua Hedionda Lagoon, Carlsbad, California. Fourth Year Status Report. Report prepared for Southern California *Caulerpa* Action Team. 12 pp.
- Miller K.A., Engle J.M., Uwai S. and Kawai H. 2006. First report of the Asian seaweed *Sargassum filicinum* (Fucales) in California, USA. *Biological Invasions* (in press).
- Nicholson N.L. 1979. *Sargassum muticum*: a Japanese seaweed continues moving into new waters. 2nd National Coastal Shallow Washington Research Conference 167.
- Norton T.A. 1981. *Sargassum muticum* on the Pacific coast of North America. *Proceedings of the International Seaweed Symposium* **8**: 449-456.
- Nyberg C.D. and Wallentinus I. 2005. Can species traits be used to predict marine macroalgal introduction? *Biological Invasions* **7**: 265-279.
- Piriz M.L. and Casas G. 1994. Occurrence of *Undaria pinnatifida* in Golfo Nuevo, Argentina. *Applied Phycology Forum* **10**: 4.
- Ribera M.A. and Boudouresque C.F. 1995. Introduced marine plants, with special reference to macroalgae: mechanisms and impact. *Progress in Phycological Research* **11**: 187-268.
- Scagel R.F. 1956. Introduction of a Japanese alga *Sargassum muticum* into the northeast Pacific. *Fisheries Research Paper St. Washington* **1**: 49-58.
- Silva P.C., Woodfield R.A., Cohen A.N., Harris L.H. and Goddard J.H.R. 2002. First report of the Asian kelp *Undaria pinnatifida* in the Northeastern Pacific Ocean. *Biological Invasions* **4**: 333-338.
- Yoshida G., Murase N and Terawaki T. 1999. Comparisons of germling growth abilities under various culture conditions among two *Sargassum horneri* populations and *S. filicinum* in Hiroshima Bay. *Bulletin of Fisheries and Environment of Inland Sea* **1**: 45-54.
- Yoshida T. 1983. Japanese species of *Sargassum* subgenus *Bactrophyucus* (Phaeophyta, Fucales). *Journal of the Faculty of Science. Hokkaido Univ. Ser. V.* **13**: 99-246.

Received 1 February 2007

Accepted 27 February 2007

